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The potential cost from passengers and how it impacts railway maintenance and renewal decisions

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Abstract

To plan Maintenance and Renewals (M&R) for the heavy railway lines, scheduling work possession time and deciding the closure of railway line are quite challenging for Infrastructure Manager (IM) at tactical planning level. As usual, the direct costs such as the materials costs, man power price and machinery costs are the important factors for IM to evaluate all the alternative schedules. At the same time, the potential cost from passengers is also crucial to minimize the impacts to the society.

A phase-based planning toolkit is developed to help IM to plan and compare project proposals from a wider cost scope, integrating the passenger loss and direct costs into the comparison at planning stage. Passenger loss is estimated basing on the potential delay time values.

The case study shows the potential cost from passengers is one of the key factors impacting the rank of M&R options. It even dominates the overall cost comparison for the busiest railway stations. In such case, the track closure time has to be decided according to the passenger loss instead of the direct costs. Sometime the best proposal for society might be the most expensive solution for IM. Therefore the potential passenger loss is not something that can be ignored at planning stage.

Keywords: Passenger Costs, Railway Maintenance Planning, Railway Closure Time Evaluation

1. Introduction

1.1. Background

Infrastructure Manager (IM) has been separated from the restructuring of railways in the last decades (1997 in Denmark). The objective of restructuring is to make railway more competitive. It mainly brings the following challenges to infrastructure managers.

Firstly, the better performance such as more trains per hour, longer operating hours and better punctuality is required by government and Train Operation Companies (TOCs). More Maintenance and Renewal work are needed to remain the railway infrastructures in good order.

Secondly the restructuring transfers the rail network ownership to IM so that the focuses can be put on the railway infrastructure. The cost oriented policy was made for IM to improve the project cost efficiency. Under the increasing budget pressures, costs therefore become the most important factor impacting the choice of M&R implementation.

At last, railway as the most safety reliable traffic mode transports millions of passengers on daily basis. Any closure of a railway lines on the maintenance and renewal purpose can delay a lot of passengers, creates traffic congestions and further impacts to the whole society.

1.2. Motivations

When the total amount of the M&R work had been decided from the strategic planning, how to plan the possession working time and decide the closure time of the railway line are the main questions.

Limiting the analysis only on the M&R direct costs such as the materials costs, man power and machinery costs will be risky to under-estimate the railway project impacts. Because a low cost maintenance plan, for instance totally closing a line at rush hours, is not the most cost efficient solution at all for the passengers. If the railway is closed long enough, the impacted passengers could choose personal car to do the transport and leave the public transport in a long run.

Therefore it is necessary to investigate how the potential cost from passengers impacts the ranking of alternative proposals from a wider cost scope.

2. Objective and Approach

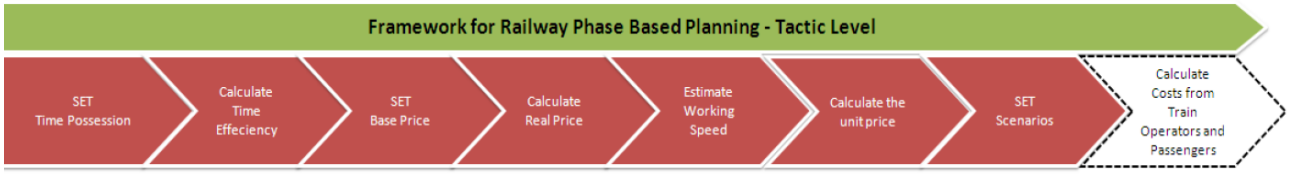
The main objective is to find an approach converting the passenger loss caused by maintenance and renewals into monetary costs. Integrating it into the cost comparison to investigate how it can impact the railway M&R decision at tactical level.

A so-called “railway phase-based planning toolkit” is developed to plan and compare the railway infrastructure project proposals from a larger cost scope. The new planning toolkit calculates the construction costs by taking the working possession time into account. The passenger loss caused by the construction work is also integrated into the analysis.

It is a phase-based approach in which different parts of the costs are calculated in separated phases. The idea is that the toolkit can be easily extended or research in details in particular phase. Passenger loss is built in Phase 8 and can be either included or excluded to the final cost comparison. How the passenger loss impacts the proposal ranking can be then investigated and discussed.

In the framework, the planning processes and cost calculation are constructed into the following phases,

Figure 1 – The Tactical Planning Phases



3.1. Direct Cost Calculations

The "Green-field market price" (the price in the situation where people work 37 hours at workdays), will be used to calculate more accurate actual spends by considering the working possessions, job type and working efficient etc… The calculation is divided into 7 stages indicated by the red arrows in Figure 1. It includes,

- Setting work possessions
- Calculating working efficiency
- Setting green field market price
- Calculating the price for each working possessions
- Estimating working speed and,
- Setting scenario and Estimating the actual costs

It is very important to do the transfer because the same amount of workload can cost quite differently in different working possessions. It estimates from Fehmarn project that the difference can be up to 10%.

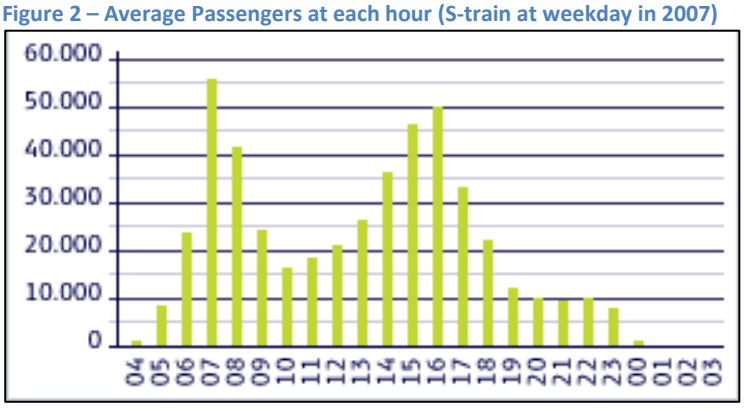
3.2. Passenger Loss Estimation

The way to calculate passenger loss is based on the potential passenger delays. Value of Time (VoT) is used to transfer the delay minutes into monetary values. The following formula is showing the calculation of the potential loss for passengers.

$$Passenger\ Loss = Number\ of\ passengers * Cumulative\ Delays * VoT$$

Number of passengers: It can be calculated according to the traffic density (from the passenger train timetable) and the average amount of passenger per train. The number of passengers is changing from time to time but has certain seasonality in a long term. The following chart is showing the S-train average amount of passengers at weekday in 2007. At this step, many assumptions such as passenger seasonality at implementation period, potential reduction of passengers due to maintenance, train-bus delays etc. need be made.

Figure 2 – Average Passengers at each hour (S-train at weekday in 2007)



Cumulative Delays: It means the cumulated delay per passenger caused by the maintenance and renewal in the whole implementation period. It is estimated via train delay simulation according to the detailed possession plan. For example, if the line is totally closed and the train-buses have been arranged, the additional travel time on train-buses can be looked as delays. A cancelled train can be seen as a long time delay train. Simulation normally is used to estimate the delays at this step.

Value of Time (VoT): In transport economics, VoT is the amount of money that a traveller would be willing to pay in order to save time, or the amount of money they would accept as compensation for lost time.

The passenger value of time is a complex estimation which depends on many factors like passenger type, age, income and day time etc. As an example shown in the following table, there are many statistics providing the VoT for public transport in Denmark. The average passenger VoT for particular railway project has to be estimated according to passenger type mixture and travel purpose.

Table 1 - Value of Time for Public Transports

Value of Time	Unit	2008	2009	2010	2011	2012	2013	2014
Unit Value of Time - Public Transport								
Travel Time								
Household	kr./hour pr. person	80	76	77	78	80	81	83
Employee	kr./hour pr. person	338	322	325	329	335	342	350
Others	kr./hour pr. person	80	76	77	78	80	81	83
Waiting time and delay time								
Household	kr./hour pr. person	160	153	154	156	159	162	166
Employee	kr./hour pr. person	675	643	650	659	670	684	700
Others	kr./hour pr. person	160	153	154	156	159	162	166
Transit time								
Household	kr./hour pr. person	120	114	116	117	119	122	125
Employee	kr./hour pr. person	506	482	488	494	503	513	525
Others	kr./hour pr. person	120	114	116	117	119	122	125

3.3. Cost Comparison

When all the direct costs and passenger loss are calculated for each possession plan, the cost comparison was normally used to identify the most cost-efficient plan. In the comparison, direct costs and passenger loss ranks the alternative proposals; the project time in calendar days is used to indicate the impact period. The comparison example chart can be seen in the following case study.

3. A Case Study

4.1. Case Brief

Two of S-train stations, *Allerød* and *Nørreport* Stations, are used to illustrate how the planning toolkit estimates the costs from Infrastructure Manager and Passengers.

Nørreport Station is the busiest station in the center of Copenhagen, serving 165,000 people on daily base. It is a main transit station connecting the intercity trains, S-trains and the Metro. At the S-train layer, there operates six main lines on both directions in rush hours.

Allerød Station is the S-train station in north of great Copenhagen, out of the urban city area. Line E is the only service line running through the station. There is no train transit in the station. Different from *Nørreport* station, the amount of passengers is small. The most passengers use the station in rush hours.

Figure 3 - S-train Network in Copenhagen

4.2. Main Assumptions

The assumption is made that a 500 meters' track and drainage system need be renewed at *Nørreport* Station and *Allerød* station. The renewal can be done through two men and one machine. The direct cost is therefore calculated in the below structure.

Table 2 - Cost Structure

Job Types	Material Cost	Machine Cost	Man power Costs	Total
Tracks and drainage	10%	49%	41%	100%

There are 4 working possession plans as shown in the following table.

Table 3 - The Settings of Working Possession Time

#	Time Possession Type		From	To	
1	Day Working In Internals	Monday - Friday	08:00		15:00
2	7 Hours Night Working	Monday - Friday	22:00		05:00
3	Weekend Working	Friday	22:00	Monday	06:00
4	Total Closure	All days	00:00		00:00

Day working in intervals: It means the renewals are implemented between running trains. The railway services are remained. The safety settlements are requires before and after every renewal work. The working efficiency is very low. It normally takes the longest days. Passengers will be partially impacted because the trains will run every 20 minutes instead of 10 minutes at *Allerød* station. It is not a feasible solution for *Nørreport* station because the interval time at *Nørreport* station is only 2 minutes.

7 hours Night working: The renewal is implemented in the night. The man power costs 200% of the market workday price; while the prices for machine and materials are un-changed. The working efficiency is relative low. Natural time loss is around 15% at night. The safety settlements are needed before and after the renewal work, twice per night. Train-buses are arranged to replace train services.

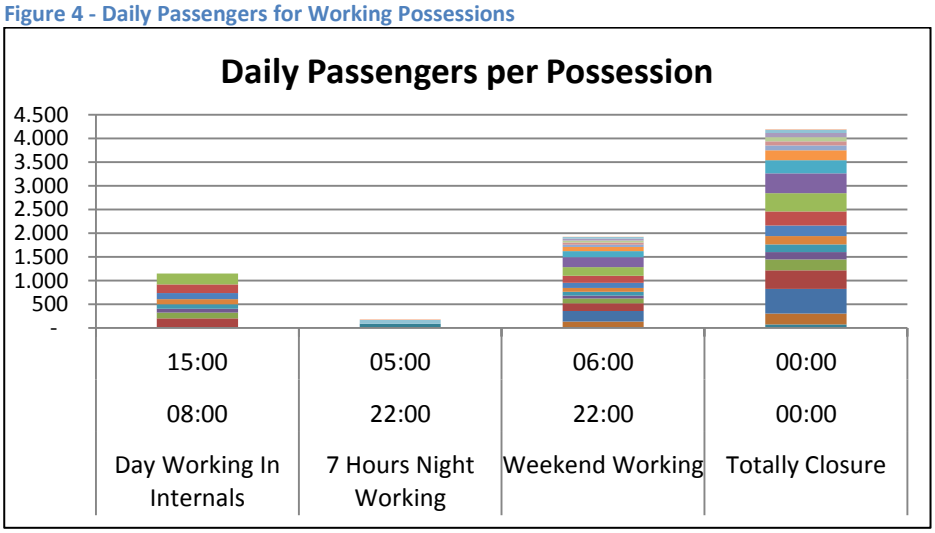
Weekend working: The renewal is implementing in the weekend. The tracks are closed from Friday evening to Monday morning. Man power costs 200% in the night and 150% in the weekend day time. There is natural time loss 15% at night. The safety settlements are required before and after the renewal work, twice per weekend. The working efficiency is relative high. Even the total working time is short but the project still takes long time in calendar days (The man and machine are still occupied between weekends). Passengers are impacted in the weekends. The train-buses are arranged to carry passengers.

Total closure: The track is totally closed for all days. The working speed is the fastest. The time loss due to the safety settlements is also the shortest. But passengers are impacted the most. They have to use either the train-bus or other transport modes to do the transport. The project can be done in the minimum calendar days. The average man power price is relative low (not equals to the green-field market price). In general, it is the cheapest solution for Infrastructure Manager.

4.3. Passenger Loss

The daily amount of passenger per hour can be calculated according to the train time table and average passengers on each train. The following table shows the result (for line E) at *Nørreport* Station.

Figure 4 - Daily Passengers for Working Possessions



The average passenger VoT per hour is estimated according to the mixture of passenger (Employee's time value is higher than household. In rush hours, most of passengers on the trains are for working purposes) and the transit activity (The value of transit time value is higher than normal travel time, at *Nørreport* Station the value of time per passenger is therefore higher than *Allerød*).

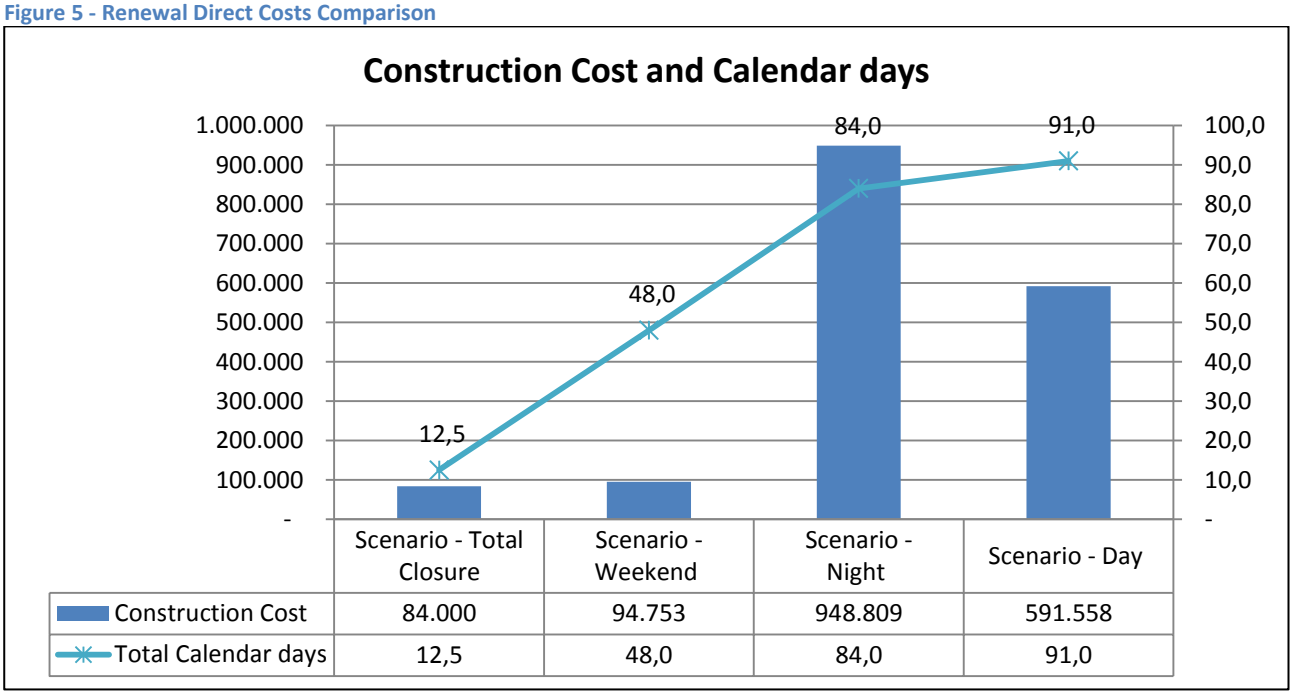
The assumptions are made that the train-bus will delay each passenger 15 minutes. When the renewal is implemented between the running trains, each passenger is assumed have 5 minute delay caused by the increased interval time from 10 minutes to 20 minutes.

The total number of passengers in general is decreasing when the train-buses are arranged to replace the existing rail service. The case study doesn't count this to keep simple.

4.4. The Comparison Results

Without taking the passenger loss into account, the direct costs comparison chart is showing in the following figure.

Figure 5 - Renewal Direct Costs Comparison



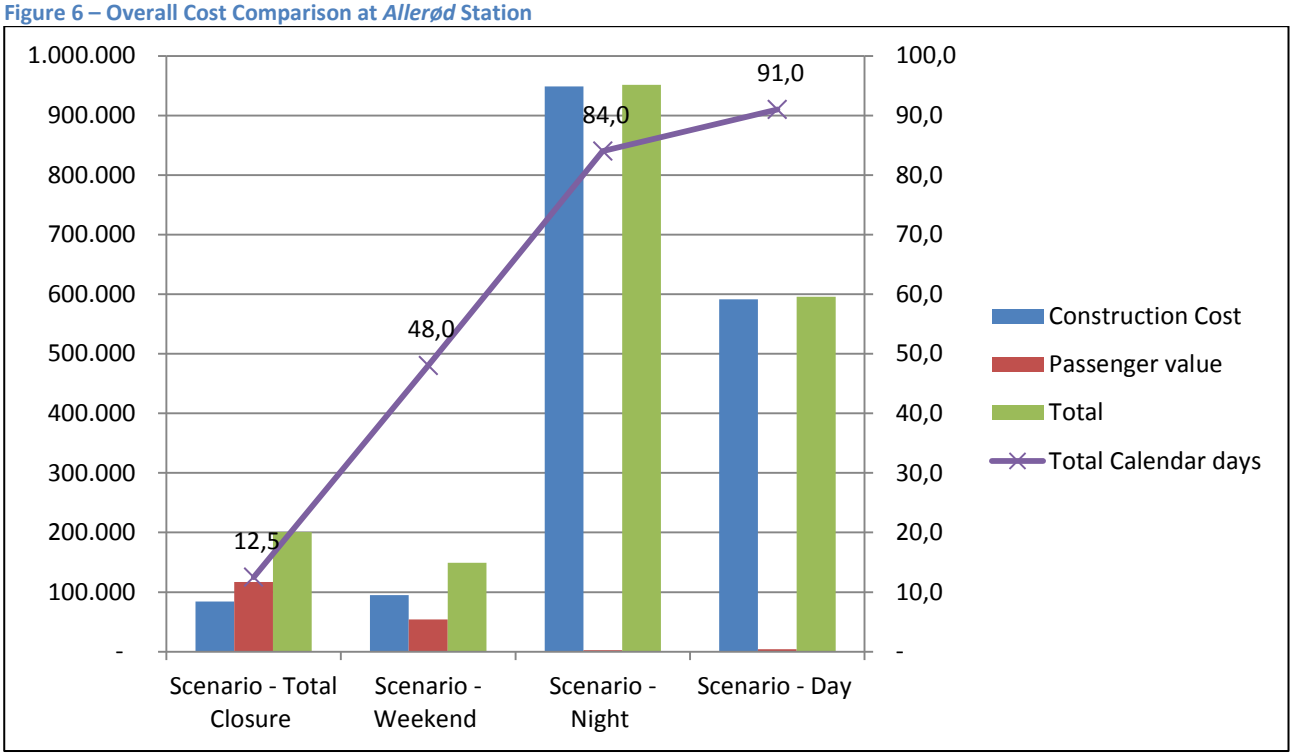
It can be concluded that,

- The solution of total closure is the cheapest solution which takes only about 13 calendar days.
- Working in the weekend is the second best option where the renewal costs is slightly higher. It takes 6.3 weekends, around 48 calendar days in total.
- Night working is the most expensive solution, more than 10 times more expensive than the total closure solution. It takes long time, 84 nights to complete the renewal work.
- Renewing the line together with the running trains is the second expensive solution but with the longest implementation calendar days.

If the passenger loss is included, it gives the different cost comparison result. At *Allerød* Station, the passenger loss is not as important as direct costs in general. The impacts only give to the total closure and weekend working scenarios. There are very few passengers in the night so that the passenger loss doesn't impact significantly. Working between the running trains keeps the passenger loss at low level but it is still a second expensive solution.

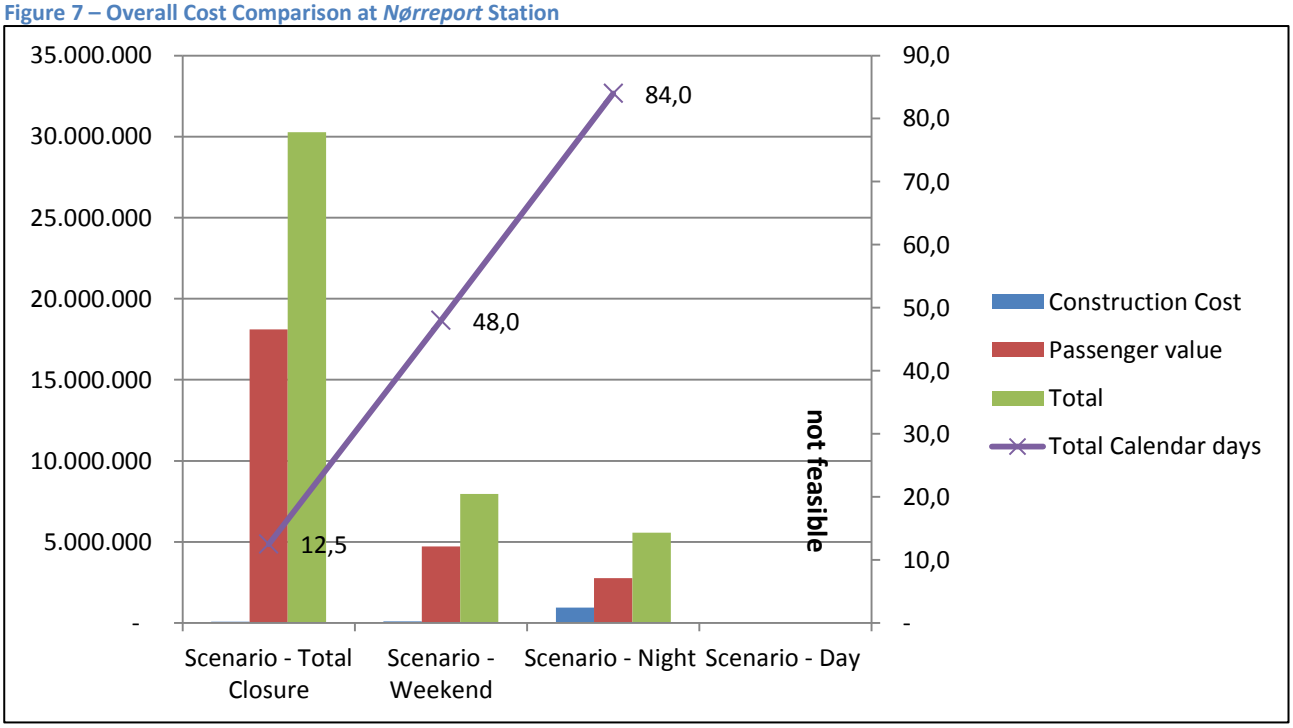
All in all, working in the weekend becomes the best solution replacing the total closure for *Allerød* station.

Figure 6 – Overall Cost Comparison at *Allerød* Station



When the traffic is heavy and the most passengers are doing transit, like *Nørreport* Station. The most cost-efficient solution is changing to night working scenario when counting the passenger loss. The following chart illustrates that the passenger loss is dominating the total cost comparison due to the higher VoT and more impacted passengers. It concludes that night working is a wise choice for *Nørreport* Station, even though it is the most expensive solution for IM.

Figure 7 – Overall Cost Comparison at *Nørreport* Station



4. Conclusion

The restructuring of railways results in an increasing maintenance and renewal requirements, so that the good quality tracks can run more trains per hour, longer operating hours and achieve a better punctuality. However, the constant budget and increasing operation restriction put more and more pressures to infrastructure manager. IM has no choice but focusing on costs when planning work possession time and deciding the closure of railway line at tactical planning level.

However, railway transports millions of passengers daily. Any closure of a railway lines on the maintenance and renewal purpose can delay a lot of passengers, and give the impacts to the whole society. The low cost maintenance and renewal plan is not always the best solution for passengers. In order to minimize the overall impacts, it is necessary to evaluate the alternative options from a larger scope, including the passenger loss into the overall costs to rank the proposals.

The article introduces a phase-based planning toolkit which integrating the passenger loss and direct costs into the comparison at planning stage. Passenger loss is estimated basing on the potential delay time values. The case study of S-Train stations shows the potential loss from passengers is one of the key costs impacting the railway closure decision. Especially for the busiest railway section, it even dominates the result of the overall proposals' ranking. It is therefore required to plan the railway closure time according to passenger loss. It could be a very hard decision for infrastructure manager because in some case the chosen solution might be the most expensive one for them.

Reference

[1] Data- og Modelcenter, "Transportøkonomiske Enhedspriser", version 1.3, Instituation for Transport (July, 2010)

[2] R. H. FISCHER and A. ZOETEMAN, "Development of a quantitative performance model of track sections: A decision support tool for rail infrastructure maintenance policymakers", Delft University of Technology, the Netherlands (2008)

[3] RAMBØLL, "Notat prissætning af tillæg for sporspær-Ringsscenarier", (2011)

[4] R.LI, "Framework for Railway Phase Based Planning", Master thesis, DTU Transport, Denmark (2012)

[5] Larsen M. K., "Coding long term forecasts" pp. 2-9, 13106 GIS and Road Traffic Planning for MSc students, DTU Transport, Denmark (2010)

[6] Elisabetta Cherchi, "Discrete choice models", pp. 17-22, 13135 Discrete choice models, DTU Transport, Denmark (2012)